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The general design of a digital stills-storage system for use with an electronic rostrum colour camera

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THE GENERAL DESIGN OF A DIGITAL STILLS-STORAGE SYSTEM FOR USE WITH AN ELECTRONIC ROSTRUM COLOUR CAMERA

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Summary

The design of a television stills-storage system is described which, in conjunction with an electronic rostrum camera, will generate television sequences including animation effects. Thus, the use of photographic film can be avoided in preparing such sequences for television.

The system uses a computer-type disc-pack to store digitised colour television component signals, mainly from the rostrum camera. Decoders for a PAL signal input to the system are discussed briefly. The stills-storage system includes an interpolator to generate an interlaced picture from one stored field, mixing and keying facilities and a control system which enables output sequences to be pre-programmed. Further Research Reports will describe particular aspects of the stills-storeage system in greater detail.

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1. Introduction

Within the BBC television service, the need has been identified for an electronic means of storing still pictures and replaying them at a sufficiently high rate to enable animated effects to be generated. Such a system would be capable of preparing television programme sequences in a similar way to that done with film rostrum cameras but avoiding the use of photographic film. Compared with film, the main advantages of electronic recording and processing for the present application are:

(i) The output is available for immediate replay and review, and can readily be subjected to further processing and re-recording.

(ii) Movement portrayal with the 50 fields per second television system is significantly better than with the 25 frames per second television film system.

(iii) Pre-programmed automatic features can be more readily installed in the electronic system.

Despite the disadvantages of the film medium, complex operational procedures have been developed, in association with the rostrum camera, which enable sophisticated effects to be produced. Not only will the electronic replacement be required to generate such effects but, because of the need to integrate the electronic system with existing practices, the preparation of artwork and 'shooting menus', etc. should be as similar as possible to that used in the conventional film-based system. Further, the control system for the electronic stills-store should enable it to be operated by staff familiar with the conventional system.

The electronic stills-storage system to be described is being developed for installation in an experimental television post-production area. It will be used mainly to store pictures from a television rostrum camera and generate, in real time, animated sequences which can then be recorded on a video tape recorder. To enable complex effects to be generated which require the combination of stills by mixing or keying, the stills-storage system is to be provided with some signal processing facilities. These facilities are being instrumented with the signal in digital-component form to avoid signal quality impairments that might accumulate in the conversions between the digital-component and analogue-composite forms where complex processing operations require the repeated processing and storing of a still. Although the main input to the stills-store is normally fed from the RGB output of a television rostrum camera, PAL decoding facilities are provided to enable signals from analogue PAL sources to be applied to the stills-store. The uses for this facility include the addition of special effects to programme recordings where still pictures are derived from studio sequences.

The performances of many of the units for the stills-store have been established. The television signal is stored, on a computer-type disc pack, in digital component form using 12 MHz, 4 MHz, 4 MHz sampling rates. Storage is provided for 800 pictures (1,600 fields) which, subject to certain restrictions, can be made available as a sequence at normal television rates; if all the stored pictures were required as a simple sequence, the sequence length would last 32 seconds. In practice, programme sequences usually contain passages where the same picture is required more than once, and sequences of several minutes duration can be provided using this stills-storage system.

2. System description

2.1. General

A schematic diagram of the stills-storage system is shown in Fig. 1. The disc-drive and its ancillary units are interconnected by a series of digital video buses which are capable of being extended to enable further units to be added, or to enable the stills-store system to be interconnected with other digital video studio systems. The control system controls the disc-drive, its ancillary units and the interconnection nodes of the bus system, and provides the man/machine interface. The control system is not included in Fig. 1 but is discussed in Section 5. The main features of the different units shown in Fig. 1 are discussed below, and the processes of PAL decoding and vertical interpolation (to generate an interlaced

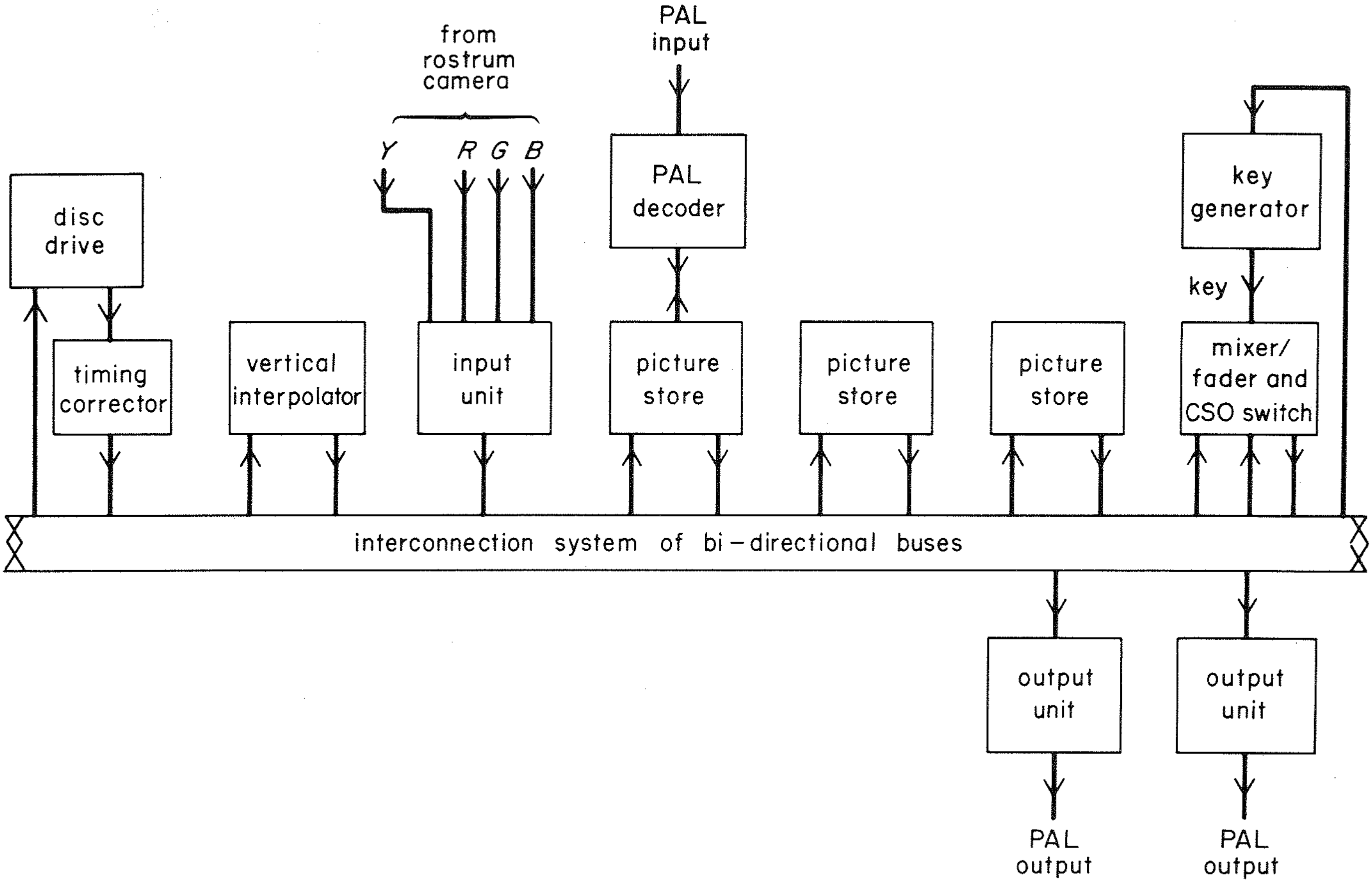

Fig. 1 - Schematic of stills-store system

picture from one stored field) are discussed in more detail in Sections 3 and 4 respectively.

2.2. The disc-drive

The disc-drive uses a standard 11-high disc-pack (IBM 3336 Mod 11) with 20 magnetically coated surfaces, two of which are used for control purposes, and is modified so as to lock the pack rotation to the 50 Hz television field frequency. It is also equipped with special heads to provide a high data-recording rate and a fast head-actuator to move the heads, from one 'cylinder' of tracks to the next adjacent cylinder, within the television field-blanking interval. One television picture (two fields) is recorded on each cylinder, and the heads are multiplexed in two groups of nine, with nine sets of record/replay electronics, so that one television field is recorded or replayed during each revolution of the pack. Up to 800 cylinders are used for recording digital television signals and some additional cylinders are available for storing a library index and other control data for the stills-store control system.

In the present application, the disc-drive is being used as a random access store for television pictures and it would be very advantageous if the pictures could be read out at full television rate in any order. However, to move the heads a distance greater than that to the adjacent cylinder takes longer than the television field-blanking interval and would therefore result in a loss of some of the active picture area. This problem is largely overcome by providing the stills-storage system with a number of semiconductor picture-store buffers, and by ensuring that stills which are required as an output sequence are stored on adjacent cylinders of the disc-pack.

2.3. RGB input unit

The RGB input unit constitutes the main source for the stills-storage system and is normally fed from the rostrum camera. The analogue RGB signals are converted, in this unit, to digital *YUV* samples at the appropriate sample rates. Monochrome signals can also be applied via this unit, mainly to provide keying signals for the mixer/fader unit.

2.4. Mixer/fader unit with chroma-key generator and switch

This unit is still under development and will provide for mixing, fading and switching between two signals possibly using a third signal to provide the keying waveform. Where a complex effect is to be built up requiring the combinations of more than two stills, this will be done in stages (not in real time) and the intermediate results stored temporarily on the disc-drive or in any one of the semiconductor buffers.

2.5. Output units

The two output units shown in Fig. 1 provide the main analogue outputs from the stills-storage system for interconnection with other analogue PAL studio systems or video tape recorders, and for monitoring purposes. Each output unit has a digital component signal at its input and converts this digitally to a PAL signal before digital-to-analogue conversion.

2.6. Picture-store buffers

Three picture-store buffers are shown in Fig. 1. One of these is associated with the PAL decoder but is available as a general picture-store buffer, to be used interchangeably with the other two, when PAL decoding is not involved.

Three picture-store buffers are provided so that a still that is held in one buffer can be keyed into a still from the disc-drive, using a keying signal derived from a further still held in a second picture store buffer; the third picture-store buffer is available for storing the result. Further applications of the buffers include the temporary storage of stills which are not recorded on adjacent cylinders of the disc-pack; the more buffers that are available for such purposes, the less the restrictions placed upon the sequences that can be made available in real time.

A facility is also provided to allow a limited degree of animation by the vertical and horizontal displacement of signals held in a picture store. The degree of picture movement can be controlled manually or pre-programmed and this facility will be particularly useful when a small object is to be animated and combined with other pictures either from the stills-store or the rostrum camera.

3. Decoding to provide a PAL input to the stills-store

3.1. General

When PAL encoded signals are fed to the stills-store they must be decoded to the *YUV* component form used in the stills-store. The combination of operations, where the PAL signal is first decoded and a still picture formed from one input field or picture and then finally re-encoded as PAL which is eventually decoded a second time in the viewer's receiver, placed very stringent requirements on the properties of the first decoder.

The details of the decoders for the stills-storage system will be described elsewhere.[1] However, before a brief description of the decoders installed in the stills-storage system, the effects of the combination of operations described above on any cross products produced in the first decoding process are discussed.

3.2. The effects of cascaded decoding and re-encoding in the present application

Fig. 2 illustrates the range of cross effects that can be generated when two PAL encoding and decoding operations are cascaded. These will be described first without the stills-store system being introduced between the two operations.

In the first encoder and decoder, an original luminance component Y and colour difference component C give rise to luminance and colour-difference components Y^1 and C^1 respectively. (The superscripts indicate that these have been modified by the responses of the first encoder and decoder channels.) Cross products are also generated. C^{1*} is cross luminance, i.e. chrominance which appears in the luminance channel as crawling dots. Y^{1*} is cross colour, i.e. luminance components which are demodulated as chrominance and appear as changing coloured patterns. From the second encoder and decoder, the true luminance and chrominance components consist

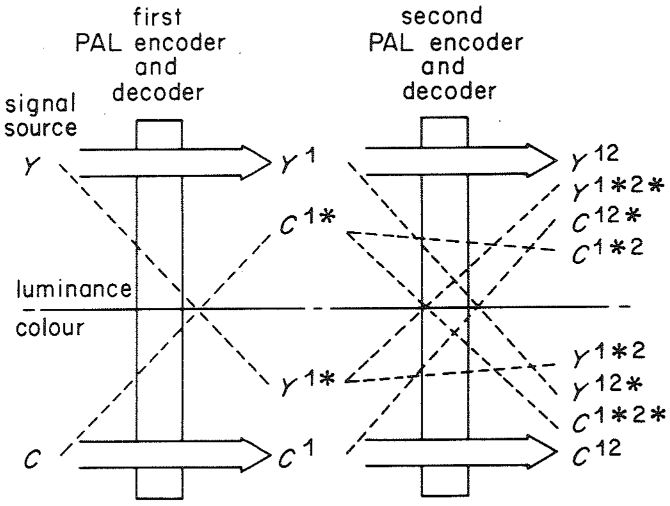

Fig. 2 - Diagrammatic representation of the source of PAL 'footprints'

of Y^{12} and C^{12} respectively. However, the cross luminance and cross colour components from the first encoding and decoding processes appear as $C^{1\,*2}$ and $Y^{1\,*2}$ and cross products are generated from each of the signals present at the input of the second encoder; $C^{12\,*}$ and $Y^{1\,*2\,*}$ are produced as luminance components and $Y^{12\,*}$ and $C^{1\,*2\,*}$ as chrominance components. Of these cross products, $Y^{1\,*2\,*}$ was originally derived from luminance but was demodulated as colour in the first decoder and remodulated to become luminance again at the second decoder. However, in the demodulation and remodulation processes this luminance component becomes changed unless the modulation phases used in the first and second encode/decode processes are the same. Similarly, $C^{1\,*2\,*}$ was derived from chrominance which has been modulated at the first encoder and demodulated at the second decoder and will only produce the same colour if both the first and second modulation phases are the same.

The effect of forming a still picture from either one field or one picture at the output of the first decoder is to freeze the cross products which would otherwise be periodic over an eight-field interval. Thus, after the second encoder and decoder, $C^{1\,*2}$ consists of frozen cross luminance and appears as a stationary dot pattern. Moreover, this pattern could beat with the crawling dot pattern, $C^{12\,*}$, to generate a flashing dot pattern. Similarly $Y^{1\,*2}$ would produce a stationary coloured pattern frozen into the picture which could beat with $Y^{12\,*}$ to generate a flashing coloured pattern. For $Y^{1\,*2\,*}$ and $C^{1\,*2\,*}$, when the output picture is generated from one stored field, the effect of freezing the cross products at the output of the first decoder is as if the modulation phases of the first and second encode/decode processes were made to cycle through eight different relative phases on successive fields. When the output picture is generated from a stored picture, the effect is as if the relative phases of the encode/decode processes cycle through four different values on successive pictures. As a result, $Y^{1\,*2\,*}$ becomes a luminance component which is phase modulated at a 6¼ Hz rate which, if added to Y^{12}, causes an overall flickering of high-frequency luminance components; similarly, $C^{1\,*2\,*}$ cycles through different phases at a 6¼ Hz rate and, if added to C^{12}, causes colour flicker in the output picture.

3.3. The decoders

In the present application, where the result is clearly intended to be a still picture, any moving or flickering effects, generated as a result of the shortcomings of the first decoder, can be particularly distracting. To minimise such effects, two special decoders have been developed to provide a PAL input to the stills-store system. The first consists of a still-picture decoder which is intended for use where a television camera is directed at some stationary artwork, model or set in a television studio and no direct access is available to the RGB output from the camera; it might also be used where still pictures have been recorded, each for several picture intervals, on a video tape recorder. The principle of operation of the still picture decoder is illustrated in Fig. 3, which shows a schematic of the basic form of this decoder. The chrominance modulation axes of a PAL colour television signal are precisely inverted after an interval of two pictures. Therefore, adding the television signals across a two-picture delay gives the luminance component and perfectly cancels the modulated chrominance components. Similarly, subtracting the television signals across the same interval gives the modulated chrominance components and perfectly cancels the luminance components. Thus, for still pictures, this decoder provides a perfect separation of the luminance and chrominance components and completely suppresses any cross effects.

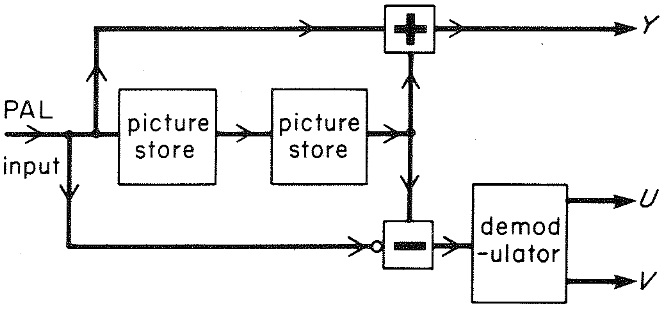

Fig. 3 - The basic form of the still-picture decoder

The second decoder is intended for use where there is some movement in the image described by the PAL signal, and the still-picture decoder cannot be used. With moving pictures, it is not possible to separate perfectly the luminance and chrominance components of a composite signal under all possible signal conditions. The moving picture decoder is still under development but good results have been achieved with a system based on the use of delays of approximately one field interval.[2] Fig. 4 shows tests being conducted with this form of decoder which has been found to provide an adequate separation for all stationary portions of the picture and no serious impairments are produced with moving pictures taken from typical television programme sequences, even when a still picture is generated from one decoded field and

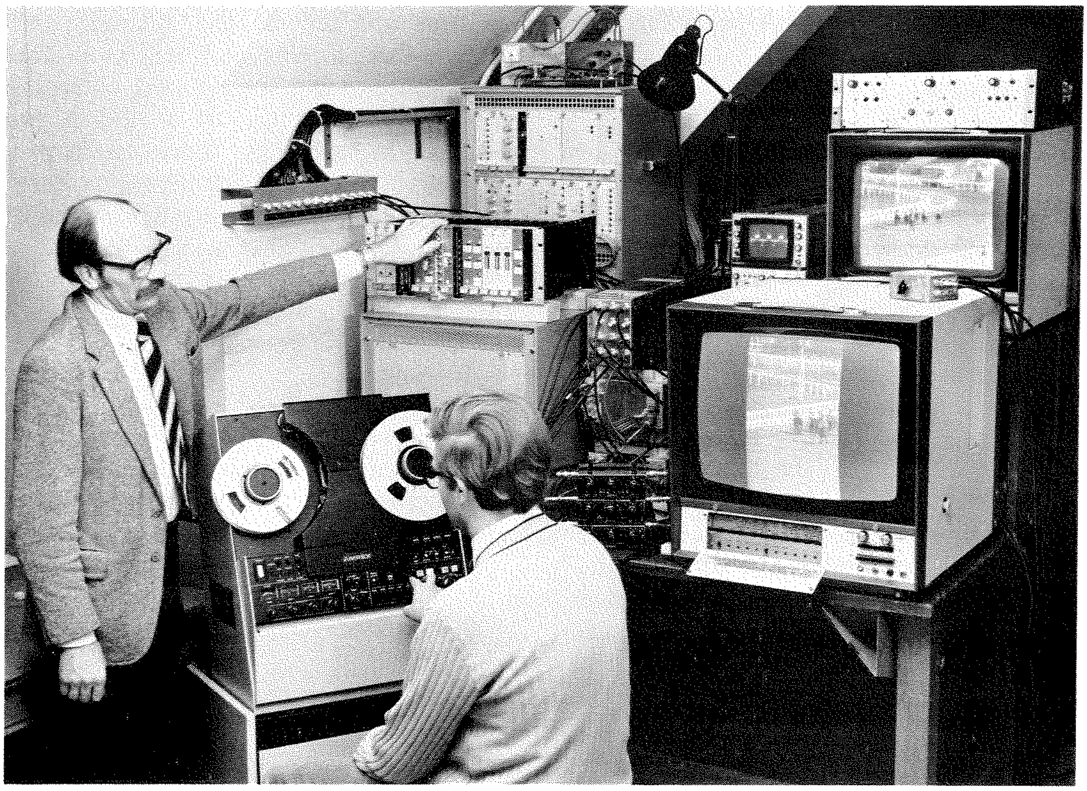

Fig. 4 - Tests being conducted with a prototype of the moving picture decoder in which half a picture was processed

applied to a second PAL encoding and decoding process. It is expected that developments of this form of decoder will further reduce the cross effects generated when programme sequences of particular critical pictures are decoded.

The operator of the stills-store system can select which of the two PAL decoders should be used for the particular work in hand, using a picture monitor fed from the output of the first decoder via a PAL encoder and conventional delay-line decoder.

4. Interpolating from a stored field to generate an interlaced still picture

The stills-store system is provided with a vertical interpolator so that a properly interlaced picture can be generated from one stored field for effects such as slow motion, reverse motion or for freezing movement.

A simple method of generating an interlaced picture from one field is to repeat that same field, displaced vertically by one picture line, on alternate fields; this causes a 25 Hz vertical jitter of the picture which can be distracting if the picture contains fine vertical detail. Alternatively, each line of the missing field may be generated by averaging the two lines of the stored field which are spatially adjacent to the output line required. Thus, a simple form of interpolation is applied to alternate fields and no vertical picture jitter results. However, the averaging process attenuates fine vertical detail on alternate fields causing this to flicker at 25 Hz. A preferred method is to apply interpolation to the lines of both output fields so that they are both subjected to the same vertical filtering. For example, interpolation coefficients of ¼, ¾ may be applied to adjacent television lines, in that order when generating say, the odd fields, and ¾, ¼ when generating the associated even fields. By these means the correct relative vertical displacement of picture information between the two output fields can be maintained so that no picture jitter effects are produced. Further, the same vertical filtering response is applied to both fields so that no flickering of high vertical-frequency components occurs. Nevertheless, the vertical filtering action implied in this approach does cause a noticeable loss of vertical picture definition.

For the stills-store system, a vertical interpolator has been developed based on the above principle but using information from other lines of the stored field and hence more coefficients, so that the loss of vertical resolution is far less significant.

5. The stills-store control system

The stills-store system is equipped with a microprocessor-based system to control the various units and enable the operator to pre-programme and edit output sequences, in terms of shots, frames and fields, using a special VDU terminal. Two levels of control are provided.[1] The first is basically a manual system intended for the experienced operator who wishes to experiment and generate new effects. With the manual system, the operator decides which cylinder of the disc-drive or which semiconductor buffer is to be used to hold each particular still picture; he also directs the transfer of information from one storage location to another. When used in this way, the pre-programmed output sequence lists are defined in terms of the storage locations of the stills.

The second level of control is more automatic and is intended for more general use. With this method of control the operator need not be concerned with the storage locations used for each picture. The control system decides where to store each still in order to achieve the desired output sequence; it also detects whether the output sequence required is beyond the capability of the stills store system. With the automatic forms of control, the operator assigns his own labels to the picture information and enters the output sequence list via the VDU terminal before the pictures are fed to the system. The control system then directs each still or picture sequence, as it and its label are applied, to storage locations such that the required sequence can be made available in real time. One benefit of this method of control is that a 'sequence to date' can be replayed, whilst pictures are being accepted as input, in order to check animation effects.

6. Conclusions

When the stills-store system is installed in a television production area in the course of 1981 it will enable television programme sequences which require the use of stills to be originated without the use of an intermediate film medium.

7. References

1. Research Reports in the course of preparation.
2. DREWERY, J.O. The filtering of luminance and chrominance signals to avoid cross colour in a PAL colour system. BBC Engineering, No. 4, Sept. 1976, p. 8.

8. Acknowledgements

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